REMR TECHNICAL NOTE CS-MR-8.1

CASE HISTORY OF UNDERWATER CONCRETE REPAIR:

REPAIR OF STILLING BASIN, WEBBERS FALLS LOCK AND DAM, ARKANSAS RIVER, USING TREMIE CONCRETE

PURPOSE: To present a case history of use of tremie concrete for underwater concrete repair.

PROJECT: Webbers Falls Lock and Dam is a unit of the McClellan-Kerr Arkansas River Navigation System. It is located on the Arkansas River at navigation mile 368.9, about 5 miles northwest of Webbers Falls, Oklahoma. The project consists of an embankment, lock, spillway, and powerhouse. The spillway extends across the left half of the existing river channel, with the powerhouse in the right half. The spillway is a gated, concrete, ogee-type structure.

The spillway stilling basin, constructed of 96 independently reinforced blocks, is 710 ft wide and about 100 ft long. The basin does not contain baffles but was constructed with a 6-ft-high end sill at the downstream end. The basin slab is stepped down from elevation (el) 421.0 at the left to el 410.0 at the right to follow the dip of the limestone foundation. For most of the basin, the minimum slab thickness is 4 ft. The basin is anchored to the foundation with No. 11 bars grouted 10 ft into rock. Reinforcement for the basin slab consists of No. 6 bars at 12-in. spacings each way near the top face for shrinkage and temperature stresses.

The stilling basin concrete was designed for a minimum 90-day compressive strength of 3000 psi. The maximum size aggregate used was 3 in. for all concrete except the top 2 ft where the maximum size was limited to 1-1/2 in. In conjunction with the repair work in March 1975, 15 cores were taken from an area where erosion damage had occurred. Thirty-four test samples were cut from these cores, and compression tests indicated a strength ranging from 2255 to 4334 psi with an average of 3316 psi.

EROSION: The erosion of the stilling basin slab was discovered during the first underwater inspection in October 1974. Damage was generally confined to the slabs near the end sill and to the end sill itself. Damage ranged from slight erosion in 12 slabs to severe erosion in 12 other slabs. In the severely eroded slabs, the floor was trenched from the toe of the end sill upstream 2 to 4 ft with an average depth of 1 to 2 ft. The trenched area was pockmarked with holes 6 to 12 in. deeper than the adjacent area. A large hole in a joint between two slabs measured 4 ft deep. The end sill had erosion damage over its entire length up to a depth of 4 ft. Reinforcing steel was damaged or exposed on most of the slabs near the end sill and on the end sill itself. Some rock was eroded downstream of the end sill, but the total extent of erosion could not be determined. The exact cause of the stilling basin damage is unknown, but the inspection revealed debris in the basin, especially large, loose rocks that had been ground smooth, indicating that the erosion could have been started by a grinding action between the rock and concrete. The inspection also revealed areas with pitted surfaces, which indicated possible cavitation.

REPAIR: Conventional concrete placed with a 10-in.-diam tremie pipe was used to fill the eroded areas. During the placing operation, a 5-1/2- to 7-1/2-in. slump was found to be best for this type operation. The mixing water was heated to about 150°F to offset the effect of the cold river water. Mixture proportions for 1 cu yd were as follows:

Material	Quantity
Portland cement, Type II	752 lb
River gravel, 1-in. MSA	1567 lb
Natural sand	1279 lb
Water	40 gal
Air-entraining admixture	7 oz

Several barges lashed together formed a work platform (Figure 1) over the area to be repaired. Prior to placement of the concrete, the damaged area was air-cleaned of silt and debris. The concrete was conveyed to the area by loading the transit-mix trucks on a barge (Figure 2) at a point about half a mile below the dam. Because of the length of time required to get from the batch plant to the work site, the cement and some water were withheld from the mix until the trucks had been loaded on the barge and were approaching the work area.

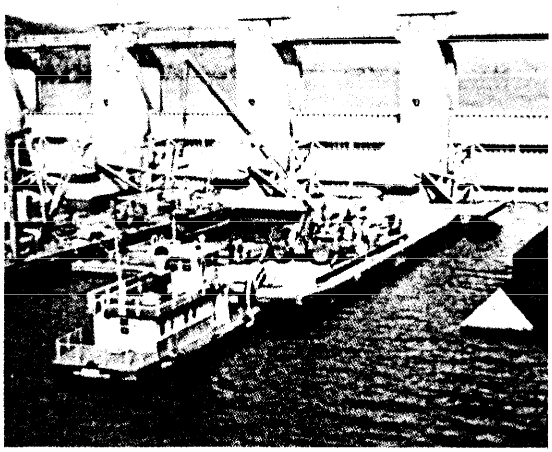

Figure 1. Work area showing equipment arrangement

Figure 2. Transit mixers carried to work site by barge

Placement was made by transferring the concrete from the truck into a 1-cu-yd-capacity bucket (Figure 3). The bucket was positioned by crane over a 1-cu-yd-capacity hopper attached to a 10-in.-ID tremie pipe (Figure 4).

A "rabbit," composed of a greased polyethylene bag filled with burlap bags (Figure 5), was placed in the top of the tremie prior to placing the concrete in the hopper. The bottom of the tremie pipe was positioned by divers (Figure 6) and rested on the surface of the existing concrete in the hole. When the fresh concrete forced the rabbit to the bottom of the pipe, the pipe was raised approximately 1 ft to eject the rabbit and permit the flow

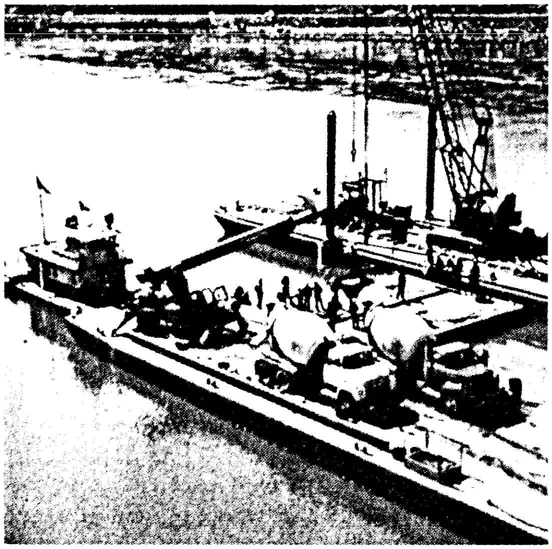

Figure 3. Placement in progress

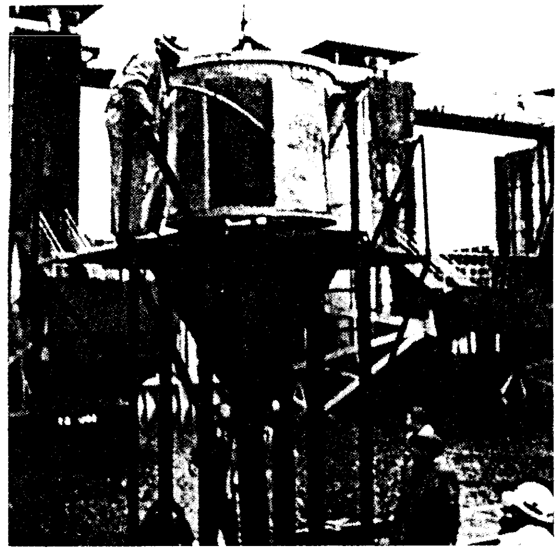

Figure 4. Concrete being discharged into hopper of tremie pipe

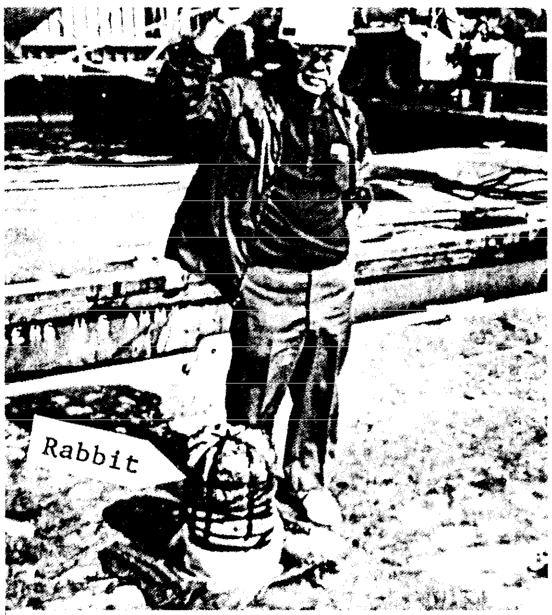

Figure 5. A "rabbit" forced the water out of the tremie pipe ahead of the concrete

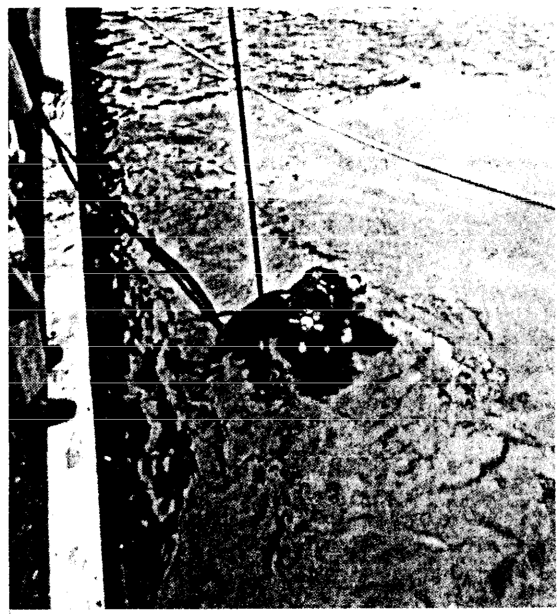

Figure 6. Army divers assisted in the repair work

of concrete. This process was repeated each time it was necessary to move the tremie pipe. The depth of the water in the stilling basin during the repair was about 40 ft. The water velocity was 3 or 4 fpm due to releases through the adjacent power plant. No releases were made through the spillway for 7 days following the concrete placement. A total of 43 cu yd was placed during two different periods. Twenty-one cu yd was placed in March 1975. After this repair proved resistant to heavy flows, an additional 22 cu yd was placed in October 1975.

COSTS: All work was done by Tulsa District personnel at a total cost of about $32,000 (1975) including surveys. A summary of the expenses involved is given in the following tabulation:

Item	Labor	Materials and Equipment
Surveys	$ 8,840	$ 8,550
Fleet	4,590	5,520
Engineering and supervision	2,800	--
Concrete	--	1,720
	$16,230	$15,790

INSPECTION: In conjunction with the repair work, a concrete core was taken through the tremie concrete placed in March 1975. A sample from this core showed a strength of 5250 psi (at about 60 days) and good bonding between the new and old concretes. In July 1975, a diving team made a cursory inspection of the repaired areas, and the areas were in good condition even though they had experienced high flows. On the basis of this inspection, the decision was made to make another placement in October 1975. The following summer, another inspection was made of the area, and both placements seemed to be in good condition. A spot survey was made in November 1979, and a comparison of the profiles of the repair area from 1975 and 1979 indicated little or no additional erosion in the stilling basin.

ENVIRONMENTAL CONSIDERATIONS: Altering release schedules to accommodate this type of repair may have to be coordinated with flow requirements for fisheries.

REFERENCES:
a. Standard practice for concrete. US Army Corps of Engineers, Washington, DC, Sep 1982. Engineer Manual 1110-2-2000.

b. Repair and rehabilitation of stilling basin, Webbers Falls Lock and Dam. US Army Corps of Engineers, Tulsa District, 1980. Engineer Circular 1110-2-218.

c. Maintenance and repair of concrete structures; annotated bibliography, 1927-1977. T. C. Liu, E. F. O'Neil, J. E. McDonald. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Sep 1978. Technical Report C-78-4, Report 1.